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A study of the changes in the near cylinder axis and the amount of cyclotorison as fixation changes from far to near

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Abstract

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INTRODUCTION

Astigmatism, as an entity, has been known to exist for over 400 years. In 1575, Pare developed stenopaic slits, presumably to correct for astigmatism. Donders, in 1860, reported that cylinder lenses would correct for astigmatic refractive errors. To Thomas Young, in 1800, however goes the credit for the first accurate description of astigmatism. Twenty-five years later, George Biddle Airy reported that compound lenses (the first sphero-cylinder lens construction to be described) were required to correct his astigmatism. The first charts designed to test for astigmatism were developed by John Green in 1866. One of these charts, the Clock Dial, is still in use today.

Even though the methods for astigmatism testing have been in existence for over 100 years, most of this testing has been performed at the far point while employing monocular techniques. Therefore, this testing occurred under conditions in which both accommodation and convergence were at their distal endpoints. This practice continued even though Dobrowolsky predicted the existence of astigmatic accommodation in 1868.

Within the past 40 years, there have been several studies that show changes in both the astigmatic power and axis when distance and other variables are varied. These changes are most evident when the testing uses binocular fixation either at far or near. In spite of these more recent studies, few practitioners today employ techniques to measure the near cylinder power or axis.

The logical reasons for not implementing near testing methods are several. First, the instrumentation necessary for such testing is unwieldy and difficult to set up. Second, no criteria have been established that can justify a cylinder change with improved visual function. And third, the incidence of these changes isn't significant. Although the first two reasons given above can't be refuted at this time, the work of Scobee, 1947, is in direct opposition to the third reason given. His work showed that 75% of the cases he studied showed a shift in the cylinder axis at near.

PROPOSED MECHANISMS

Many mechanisms and hypotheses have been suggested to explain the changes in cylinder axis and power resulting from near fixation. These attempted explanations may be categorized into 3 major groups: anatomical, optical, and physiological. These categories are discussed in the following paragraphs.

The anatomic category includes any of the many variations in anatomy that may cause a differential muscle action during convergence or accommodation. If, for example, one or several of the extraocular muscles or their sheaths inserted abnormally, convergence could produce a cyclophoria or cyclotropia. This could affect the cylinder power or axis at near. This is more than just an exercise in theory because, according to Veronneau-Troutman, 1972, cyclotropias and cyclodeviations are, "more common than thought to be...the more you look for it, the more you find it." Furthermore, if the ciliary muscle or zonule fibers were abnormal in structure of function, a change in cylinder power and/or axis could result during accommodation. Likewise, muscle paresis could also produce similar changes during convergence.

The most widely proposed mechanism contained within the optical category is that the variations in the near cylinder are caused by variations in lens effectivity due to changes in accommodation and convergence. In 1945, Hofstetter devised a formula and a computation table that showed these "effectivity" changes. A second optical mechanism that is thought to occur is due to the fact that vision at near may be directed obliquely through the spectacle lens, thereby producing astigmatic variations. However, Beau-Signeur, 1946, stated that this effect is minimal for lens powers less than 5.00 D. A third mechanism within the optical category concerns the actions of accommodation on the astigmatic interval in the uncorrected or undercorrected eye. According to this hypothesis, accommodation compensates for near viewing by placing the circle of least confusion on the retina. This mechanism is also supported by the work of Beau-Signeur, et al, which showed that if a +1.50x90 lens is placed before the eye, far point acuity is reduced by several lines; whereas, this effect does not occur for the near acuity. If, however, a +2.50 D. lens is introduced at a 40cm testing distance, thereby eliminating the need for accommodation, the +1.50 x90 lens does blur the print. Professor Roth, 1969, also concluded that these effects, which he called accommodative astigmatism, do exist. His studies used the von Helmholtz target (a test target composed of black and white concentric circles) in which fluctuations in accommodation produce the perceptual appearance of "shimmering" in certain sections of the test target. This phenomenon is offered as a possible explanation for the frequent axis changes that are measured on the same eye with some subjects. It is evident from these studies that something must be causing these changes in the near cylinder. In fact, these effects are present in many instances even when the cylinder correction, as determined by the usual monocular, far-point techniques, is in place. Even more incredible, is the finding that these phenomena may occur in persons who exhibit little or no astigmatism at the far point!! Hallden, 1974, attributed these effects to asymmetric contraction of the ciliary body. Others have advocated a tilt of the lens during accommodation as the causative agent. Since these effects can still be produced even after instillation of atropine, accommodation can not be the sole cause of the near cylinder changes in power and axis. An alternate explanation for this "accommodative astigmatism" contends that the extraocular muscles, during the act of convergence, may mechanically distort the cornea thereby producing astigmatic changes at near.

The third major category of attempts to account for the cylinder axis and power changes at near is physiologic in nature. That is, these changes result from the normal functioning of the visual system. For example, a stenopaic effect is theoretically possible when the lids are narrowed for near work. Miosis may also act to change the astigmatism at near. Yet another physiologic mechanism is that category of eye movements referred to as cyclotorsion--also called torsion. This effect was first described by Donders in 1847 and is defined as a "rolling" of the eyeball about its anterior-posterior axis. Allen, 1954, stated that the muscle most likely responsible for torsional movements is the inferior oblique, although the superior oblique and the vertical recti are most likely involved. If the inferior oblique is the primary muscle involved, then excyclotorsion would be predicted. The work of Collins and Oberhelman, 1975, and others, has found a definite trend toward the extorsion--although this is by no means a universal finding.

To summarize, there are many possible mechanisms to account for the changes in cylinder power and axis as a function of changes in fixation. In the next section, the experimental and clinical evidence regarding these changes is reviewed.

PRESENT STATE OF THE ART

One of the earliest attempts to measure the effects of torsions employed the Genothalmic kractometer, as described by Peckham in 1928. This method employed a septum and allowed for binocular testing. Peckham's studies indicated that torsion is more prevalent when oblique astigmatism is present. He concluded that torsion resulted from one or more of the following causes: an imbalance of accommodation and convergence, hypertonicity of one or more of the extraocular muscles, or latent hyperopia. He advocated visual training to eliminate this problem.

Another early attempt at torsional measurement was devised by Becher and was published in 1934. He used a haploscope to measure the amount of cyclotorsion. He studied 400 people with corrected oblique astigmatism and found that 5-8 degrees of torsion occurred at near, on the average. His measurement error was reported to be ½-1 degree. One of the inherent problems with haploscope, or any closed instrument, testing is that proximal convergence may produce different responses than would be found with normal task distances. In addition, the lighting in the haploscope is artificial and doesn't necessarily stimulate the entire retinal area; therefore, the natural environment isn't simulated. This, then could affect the amount of torsion measured. A third factor in closed instrument testing, according to Sanfilippo, 1972, is that the slide fields measure approximately 10 degrees in diameter, while the normal visual field ranges in diameter from 60 degrees in the vertical meridian to 130 degrees in the horizontal, for each eye. The exact effects of these factors on torsion measurements aren't known at this time; however, they can not be ruled out as potential variables.

Beau-Signeur, et al, studied some 500 patients in 1946 in order to determine the cylinder power and axis changes as a result of convergence. Three tests were used to measure this relationship. The first test was a subjective cylinder test at near. A cross-cylinder test at near and a dynamic retinoscopy completed the trilogy of tests. These findings were compared to the cylinder findings measured by the standard, monocular, far-point techniques. These near tests, especially the dynamic retinoscopy, are quite crude in nature;ie, the potential for measurement errors is high. However, the main criticism of this study is that the results were based largely on the patient's subjective preference for the measured changes. Although the test results indicate that about 30% of those tested exhibited a preference for the change in axis and another 5% preferred the change in power at near; it's not clear upon what grounds these preferences were made. It would be useful to know whether the near cylinder changes permitted greater clarity in the print, improved visual acuity, increased comfort while reading or whether it just "felt better." If this study and the study of Scobee, et al, in which he reported that 75% of his subjects showed a shift in the axis of the correcting cylinder at near, are both accurate then it appears that the majority of the population are able to tolerate these changes. This is a contention held variously by Roth (et al), Ogle & Ellerbrock (1946), and Veronneau-Troutman (et al).

Bannon, 1946, developed a conversion table for determining the change in cylinder power at near as a function of the far point refractive error. Along these same lines, Hofstetter, 1945, published a formula to estimate the amount of astigmatism induced at near by a lens correction that is placed at a position other than the corneal plane.

Studies by Belcher, 1964, employed photographic techniques to measure the amount of ocular torsion. Maddox's formula for secondary torsion was used to estimate the true torsional effects that resulted from convergence. His work indicated that true torsion does not occur solely to compensate for head tilts, as Marquez (1949) and Harden & Dulley (1974) have advocated.

Further work by Harden & Dulley employed both qualitative and quantitative methods. Their qualitative methods included observation of limbal blood vessesl while performing a cover test, observations of the position of the blindspot relative to the macula, and the use of a Maddox double prism. Similar studies by Ogle & Ellerbrock, et al, and Veronneau-Troutman, et al, indicate that a one degree cyclorotation produces an average of only a .2mm displacement of either a limbal blood vessel or the blindspot. Therefore, it is evident that the qualitative methods are crude. Their quantitative studies employed the Maddox rod, wing, and the double rod; the Major amblyoscope; the Lees screen; and after-images. Most of these testing procedures suffer from the problems of retinal rivalry, suppression and dissociation. In addition, according to Harden & Dulley (et al) the reliability of these methods is quite low, with the exception of the Lees screen.

Sood and Sen, 1970, used after-images and a graduated 360 degree circle to measure the torsional component of the near cylinder changes in power and axis. The major problem with after-images, unless the testing is performed in complete darkness, is that the perceptual phenomenon of vertical constancy enters in.

Several studies by Adams (1965), Blake (1972), and Hood (1968) all concluded that the near and far techniques are identical as they relate to astigmatic testing. It should be noted that these studies were more concerned with power changes than with axis changes. As stated earlier, Borish contends that the cylinder power shows little change, on the average, but it is axis changes that occur more commonly.

The study of Collins and Oberhelman, et al, concluded that over ½ of their subjects exhibited excyclovergence at near. Furthermore, they found an average increase in the near cylinder axis of 4 degrees, when the measurable cylinder was .50 D. or more. In addition to this, they found the amount of excyclorotation to increase proportionally to cylinder power, as did sensitivity to changes in axis. However, there are two criticisms of their study which must be put forth. First, they employed vectographs to measure the near cylinder (a binocular technique) and compared these findings with the monocular technique developed by Pratt. Ostensibly, this would rule out accommodation as a factor. However, the use of polaroids for the binocular testing produces a marked reduction in the amount of light entering the eyes. The result could be a differential accommodative response due to different light levels between the binocular and monocular test conditions. Therefore, these changes can not be attributed solely to convergence. The second criticism of this study concerns the fact that the torsional effects were not directly measured. Instead, it was assummed that if the binocular cylinder axis increased, then the eye extorted. Although this conclusion seems logical it may not necessarily be true. Even so, Banner, et al, reported that incyclotorsion is often measured monocularly while excyclotorsion results under binocular test conditions.

It is interesting to reflect upon the torsional effects of the eye when changing fixation from far to near. Although it is generally held that torsion does occur, it is debatable as to how much, in what direction, and for what reason does torsion occur. The amount and direction of the torsion are not predictable by Listing's law--probably because torsions are mainly a binocular occurrence.

A cyclophoria may be defined as a deviation of the vertical meridians of the two retinae away from parallelism when the two eyes are dissociated. Veronneau-Troutman, et al, reported that inadequate correction of the astigmatism results in corrective eye movements, with a cyclophoria as the result. This would then lead to a change in cylinder axis and possibly power...when switching from binocular to monocular testing, and vice versa.

Allen, in 1954, studied cyclophorias at length and concluded that they occur in "appreciable magnitude...from convergence movements in all but (the) elevated position." Cyclophorias not only lead to variations in stereopsis, the horopter, and aneisokonia; but, they also affect the location of the cylinder axis. Allen also contended that cyclophorias are not explainable by Listing's law, but that this law undoubtedly increases or decreases the magnitude of the convergence aspect of the data.

In quantification of the amount of torsion, a system of axes must be specified in order to understand the true effects of these physiologic variables. Fry, 1947, said that defining the axis system to be used is the #1 problem in eye movement studies. For example, if a planar system of co-ordinates is used, as opposed to a spherical system, the effects of "false" torsion may contaminate the findings. This is best illustrated by placing a vertical after-image on each fovea. Then, when the subject looks down or up-and-to-the-right, two after-images are seen if a flat viewing surface is used; whereas, one after-image is seen if a hemispherical background is viewed. The Biotronic Autofield perimeter and the Goldmann-Weeks adaptometer are two instruments that would qualify as spherical co-ordinate backgrounds. According to Veronneau-Troutman, et al, the effects of "false" torsion may approach 10 degrees in magnitude when viewing up-and-out by 45 degrees.

From the foregoing discussion, it is easy to see why so much confusion exists about the mechanisms involved when a torsional eye movement occurs. This is probably the reason that Harden & Dulley, et al, reported a greater interest in torsional studies among physiologists than clinicians.

In conclusion, then, it may be stated that there has been considerable study in the area of cylinder changes at near. In general, it is believed that the cylinder power changes are slight. However, there is conflicting evidence, of considerable degree, regarding the amount and direction of axis changes. Even in those studies which report changes in the cylinder axis at near, there are differences of opinion as to the mechanism(s) involved. Some believe the causative agent is accommodative astigmatism. Others argue for corneal distortion produced during convergence. Still others attribute the cause to torsional movements of the eyeball.

Finally, it should be stated that no study was found which attempted to directly correlate or compare the amount of torsion and the amount of cylinder axis change that occurs with binocular fixation.

STATEMENT OF THE PROBLEM

Although it is stated in the literature that extorsion is a possible mechanism to account for the change of the near cylinder axis, as measured with binocular methods, no studies have been published which attenpt to determine a causal relationship between torsion and convergence. Therefore, this research project was designed to investigate the amount and direction of cyclotorsion due to convergence and the change in the subjective cylinder at near, using binocular refracting techniques.

This study was based on the hypothesis that changes in cyclorotation of the eyes with increased or decreased convergence is the most probable mechanism for explaining changes in cylinder axis when comparing nearpoint and farpoint subjective refractive axis measurements.

MATERIALS AND METHODS

The experimental procedure was designed into two phases. The first phase concerned itself with the standardization of the photographic procedures necessary to objectively measure the cyclotorsion that may result from convergence activity. The second phase was directed at subjective measurements of cyclotorsion and the subjective cylinder power. Reliability for the objective photographic procedures had to be established before proceding to the second phase.

The objective measurement phase involved the use of photographic equipment. This equipment consisted of a Nikor camera back with tripod and automatic flash. The lenses used were all Nikors: a 35mm f/2, a 55mm f/3.5, and a 200 mm f/4-f/8. At least ten pictures were planned at each of the following distnaces: 34cm, 45cm, 50cm, 60cm, 3m, and 6m, for each subject. To determine reliability, all of these pictures were taken on the same individual while he fixated a target with letters subtending 20/40 acuity size at that particular fixation distance. A plum-bob, suspended from the ceiling, was positioned in each picture so that it bisected the pupil. This provided for a vertical reference in each of the pictures.

A conspicuous iris landmark was used as the reference point when the pictures were analyzed to determine the amount of cyclotorsion. This was accomplished by projecting the 35mm slides onto a light colored wall. This produced a magnification factor of almost 27x. A transparency with a protractor on it was then aligned over the projected slide with the plum-bob on the 90 degree mark and the 0-180 degree line bisecting the medial and lateral canthi. The degree reading corresponding to the location of the iris "reference" was then noted and listed in the Table of Raw Data.

The subjective measurement phase of this study involved the use of vectographic slides to perform a binocular refraction at 40cm and 6m. The subjective change in the cylinder axis between these two test distances was then noted. The testing procedure employed the Clock Dial and Cross Cylinder test charts that were seen monocularly while binocular peripheral fusion was in place.

Several different techniques were employed during the photo sessions. In some pictures, the camera and the fixation target were placed at the same distance from the subject. In other pictures, the camera remained at a fixed distance and a plate-glass beam-splitter was employed so that the fixation target distance could be varied. In addition, the lenses, aperatures, lighting, and the size of the line used to make the plum-bob were varied in an attempt to determine the best technique.

RESULTS

Sixty-four pictures, of one subject, were taken during four different sittings. Of these sixty-four, only twenty-six were used for analysis. This is because the others were unsuitable for making measurements to determine if torsion was present. There were several causes for this "unsuitability". Twenty of the pictures were unsuitable because they were black & white photos which were too small to allow resolution of the iris detail so that measurements could be made. Some of the 35mm slides simply did not develop or were not exposed properly. Some of the other slides, for example, those where the camera was at 6m, were too small to allow identification of the iris features for measuring purposes. In other words, they had the same problem that the black & white pictures had. Those slides in which a plate-glass beam-splitter was used were unsuitable because the camera could not be positioned on the subject's visual axis. And in some of the slides, the plum-bob obliterated the iris landmarks.

These pictures were taken during four different sessions over the course of a 3 month period. It was during the first session that the black & white film was used. This film was developed into 3" by 5" photographs. The remaining sessions were "shot" with the 35mm Kodak ASA 25 film. All of the film was commercially developed.

The tabulation of the raw data; ie, the readings in degrees that were read off of the slides is presented in Table I. These "readings" represent the angle that the iris reference made with the horizontal reference (the 0-180 line). These readings are listed in columns according to target distance from the cornea. The "number of photos" indicates the number of "good" slides that turned out per fixation distance. The mean and standard deviation for each fixation distance are listed at the bottom of each column. This data shows that the mean measurements increase as fixation distance increases. This corresponds to an excyclotorsion response. Also included in this table, in the

TABLE I--RAW DATA

Eye-to-Fixation Chart Distance

Number of photos	34cm	45cm	50cm	60cm	3m	6m
1	25, 25, 30	30, 31, 36	35, 40	31, 35	30, 30, 36	54
2	39, 40, 41	40, 41	42, 43, 47	38, 40, 40	34, 44, 47	53, 54, 55
3	50, 51, 53	45, 48	45, 45	46, 48, 49	44, 46	
4		45, 48	50, 50, 57	54, 55, 56	44, 45, 47	
5					44, 48, 51	
6					50, 52, 53	
7					50, 52, 59	
8					51, 54, 54	
9					56, 56, 57	
Mean	39.3°	40.4°	44.8°	44.7°	47.5°	54.0°
Stnd. dev.	10.0°	6.8°	5.0°	8.5°	8.0°	.8°
M_d'	8.0°	5.0°	4.0°	7.0°	6.0°	0.0°
M_d	5.3°					
S_d	4.2°					
Med_d	5.8°					

Table I displays the results for 3 or more photographs showing the dispersion of cyclotorsion measurements as a function of 6 different viewing distances from 34cm–6m.

The column at the extreme left indicates the number of photographs that were used for cyclotorsion measurements at each particular fixation distance.

The 2–3 entries in each row indicate the number of measurements made on each slide. For example, under the column marked "45cm", it is seen that 4 different photographs were used. The first photograph had 3 measurements taken on it while the remaining 3 photos had 2 measurements taken on each of them (see text for the method of determining these measurements).

The mean and standard deviation for each fixation distance are immediately below the table of raw data.

The mean difference (M_d') for each fixation distance is also included.

The mean difference (M_d), standard deviation of the mean differences (S_d), and the median difference (Med_d) for all the M_d' are also included... these provide a measure of the intra-photo reliability.

TABLE II--INTERPRETER RELIABILITY

Absolute Difference	Frequency "f"	Difference "d"	"fd"	"d^2"	"fd^2"
0	7	2.5	17.5	6.25	43.75
1	14	1.5	21.0	2.25	31.50
2	12	.5	6.0	.25	3.0
3	12	.5	6.0	.25	3.0
4	3	1.5	4.5	2.25	6.75
5	5	2.5	12.5	6.25	32.25
6	3	3.5	10.5	12.25	36.75
7	2	4.5	18.0	18.00	36.00
8	0	5.5	0	30.25	0
9	1	6.5	6.5	42.25	42.25
10	1	7.5	7.5	55.25	55.25
11	0	8.5	0	72.25	0
12	0	9.5	0	90.25	0
13	1	10.5	10.5	110.25	110.25
	N=61				398

$Med_d = 2.5^\circ$

$M_d = 2.9^\circ$

$S_d = 2.6^\circ$

The distribution of measurement differences found with repeated measures on the same slide are tabulated above.

The differences, which are listed in the extreme left-hand column, were found by noting the absolute differences between individual measurements taken on the same slide (see Table I for these raw measurements).

The second column represents the frequency that each of the "absolute differences" occured.

The remaining 4 columns show the statistical data that was used to compute the mean difference and the standard deviation of the difference and are included in this table for completeness only.

The median difference (Med_d), mean difference (M_d), and standard deviation of the differences (S_d) are shown below the table.

far right-hand column, are the mean differences (M_d) for each of the six fixation distances. These were obtained by taking the mean of the repeated measures on each slide and subtracting it from the mean of all the measurements at that distance. This resulted in six mean differences, one for each fixation distance. Then the mean of these six numbers was calculated. The end result of all of this was the determination of the inter-photo reliability. This reliability was computed to be $\pm 5.3^\circ$ with a standard deviation of 4.2°.

An analysis of the interpreter reliability, employing repeated measurements on the same photograph and using the twenty-six "good" slides, is found in Table II. This data was obtained by taking the multiple measurements made on a single slide and subtracting them, in turn, from each of the other measurements made on that slide. In this way, an indication of the intra-photo reliability could be ascertained. The mean difference, median difference, and standard deviation of the differences are included with the data in Table II. This data shows that the difference between successive readings on the same slide averaged $\pm 2.8^\circ$ with a standard deviation of 2.6°.

DISCUSSION OF RESULTS

From the results, it must be concluded that the measurements obtained in this study were not sufficiently accurate to reliably and validly measure the amount of torsion produced when changing fixation from far to near. This is best seen in Table I where the measurements are shown to change by as much as 24 degrees (the range is 25-59) and the means change by as much as 14 degrees. These differences include both torsional effects as well as experimental error. However, this wide scatter in the results is so large that even with cyclotorsion present, these findings are not reliable.

The wide range in the findings may have been due to several factors. One, it was difficult to be certain that the same iris landmark was being used as the reference from one slide to the next. This arose because of minor differences in lighting, film development, head position, and the accuracy of focusing the camera. Two, the pupil size changed considerably from one photo to the next, due to changes in the lighting and due to changes in fixation distance. It is very possible that these changes in pupil size may have produced changes in the location of the iris reference point. These factors all interacted to produce slides that appeared strikingly different even when the same camera distance, fixation target, and ambient light were used. Three, changes in the camera-to-subject distance were a confounding factor. Greater distances produced greater measuring errors due to the increased difficulty in positioning the camera on the subject's visual axis. And four, it is logical to assume that the camera position, which changed as the fixation distance changed, was the largest source of variability in this study.

One interesting tendency does appear to be present in these findings. That is, it appears that, as fixation changes from far to near, the mean measurements exhibit a definite trend toward excyclotorsion. Although the absolute amounts of change, which is what this study setout to measure, are not reliable, it is apparent that excyclotorsion may be present in this one individual and that a change of 5° in the binocular refraction, in the same direction as the excyclo response, is also present in this individual.

Another interesting finding appears when one notes that the repeatibility of the measurements is fairly good when the same slide is used. This interpreter reliability, with better equipment design, could reasonably be expected to improve to $0^{\circ}\pm 2^{\circ}$. This indicates that the technique of photographically measuring cyclotorsion is possible.

SUGGESTIONS FOR FUTURE RESEARCH

Although this study failed to produce concrete evidence to quantify the amount of cyclotorsion that occurs with convergence, it did show an excyclotorsion for one subject that resulted from convergence. In addition, it has shown that measurements, using iris crypts as landmarks, are repeatable with a fair degree of reliability.

Due to delays in the receipt of funding monies for this project, which were beyond our control, this study was not afforded ample time to refine and perfect the techniques needed to obtain data that was accurate enough to permit a correlation with the changes in the binocular near cylinder axis. However, it is felt that if the following steps are taken, more accurate and more reliable data would be obtainable. The cornea-to-camera distance should be kept constant to eliminate constant repositioning of the camera. A biteboard is needed to eliminate head-tilts. A beam-splitter or asymmetric convergence is desired to permit more accuracy in keeping the camera on the subject's visual axis. A miotic would eliminate the effects that changes in pupil size might have on the position of the iris landmarks. However, it might reduce the accuracy of the cylinder axis determinations. In addition, subjects who show at least 3° and preferably 5° or more change in the binocular near cylinder axis are the most desirable for use as subjects since this is the reliability threshold of the photographic techniques. This would necessitate taking many slides and many binocular refractions on each subject. All of this points to the fact that this technique is not clinically useful in predicting the change in cylinder axis using photographic methods. No easy solution is seen for objective photographic procedures for clinical purposes. At best, this remains a problem for laboratory, or non-clinical, study.

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